

Lab Procedure – LLP-AC2

Sample Preparation and Testing for Long-Life Hot Mix Asphalt Pavements

STATE OF CALIFORNIA—BUSINESS, TRANSPORTATION AND HOUSING AGENCY

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GENERAL

Long-Life Hot Asphalt Mix (HMA) Pavements are unique in their design, specifications and construction. Essentially, these projects are designed in a manner consistent with the mechanistic-empirical approach to pavement design, in which the structural section is designed taking into account the performance characteristics of HMA, the anticipated loading for the life of the pavement and the anticipated modes of failure, typically rutting (in the short-term) and fatigue (in the long-term).

It is desirable that this type of HMA pavement be constructed using a HMA in which the performance characteristics (shear and fatigue) control the mix design. This requires that the producer provides an aggregate/binder mix that will meet the required performance characteristics (shear and fatigue); and then define that mix using the traditional attributes of gradings of the aggregates, asphalt content, stability, voids and compaction. These qualities will be used during production and placement for quality control measures and, ultimately, for quality assurance. Background research that was conducted on mix design for a previous project with similar requirements (LA 710) is detailed in Technical Memorandum UCPRC-TM-1999-2, "Mix Design and Analysis and Structural Section Design for Full depth Pavement for Interstate 710".

Shear, and fatigue and stiffness mix responses are determined from the Strategic Highway Research Program (SHRP) developed Shear (Superpave Shear) and Flexural Fatigue Beam Tests. The response of the mix to trafficking under wet conditions (moisture-susceptibility) is determined from the Hamburg Wheel-Tracking Test.

It is recommended that the design binder for each mix be determined from the results of the shear tests according to the following test program:

1. Determine an initial trial mix for proposed aggregate and binder (e.g. based on Stabilometer "S" values) and laboratory compacted air-voids following standard Caltrans procedures.
2. Prepare at least three test specimens for each asphalt content over a range of binder contents at the required air void content of 3.0 ± 0.3 percent:

Note: Project specifications require performance within the production tolerance of 0.3 percent for asphalt content. It is advisable that shear tests be performed for at least

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three binder contents at 0.5 percent (mix basis) intervals bracketing the initial trial mix.

3. Test specimens for shear and select design binder content based on specification requirements.
4. Adjust aggregate gradings or asphalt content if necessary and retest until the requirements for shear are met.

It is recommended that fatigue and stiffness response be determined as follows:

1. Prepare at least six beam test specimens at an air void content of $6.0 \pm 0.3\%$ using the binder content selected from the shear test results.
Note: If one of the mixes tested is also used as a rich bottom layer with different characteristics (other than the binder) prepare six specimens at an air void content of $3.0 \pm 0.3\%$.
2. Test specimens for fatigue and stiffness at the required strain levels and determine if the specification requirements are met.
3. If requirements are not met it will be necessary to make additional adjustment to the mix.

It is recommended that moisture-susceptibility be determined as follows:

1. Prepare at least eight cylindrical specimens or four slab specimens at an air void content of $7.0 \pm 1.0\%$ using the binder content selected from the shear test results.
2. Test specimens for moisture-susceptibility at the required number of loading passes and determine if the specification requirements are met.
3. If requirements are not met it will be necessary to make additional adjustment to the mix.

TEST METHODS

1. ROLLING WHEEL COMPACTION

Asphalt specimens for shear and fatigue/stiffness testing shall be compacted according to AASHTO PP3-94: "Standard Practice for Preparing Hot Mix Asphalt Specimens by Means of the Rolling Wheel Compactor", with the following modifications:

- 5.3 - Replace with:
"Oven – a forced-draft electric oven capable of maintaining any selected temperature setting between 100 and 200°C within a tolerance of $\pm 3^\circ\text{C}$ for heating asphalt binder and aggregate."
- 8.5 - Replace with: "Spray a mild soapy solution to the base and sides of the mold."
- 10.2.5 - Replace with:
"After filling, close all containers tightly and allow to cool to room temperature. Store the asphalt binder at a temperature of $20 \pm 2^\circ\text{C}$ until the scheduled time for preheating prior to mixing. Closing the containers prior to cooling produces a vacuum seal."
- 11.4.3 - Replace with:
"Remove a pan of mixture from the oven and place the mix in the center of the mold. Level the mixture using a rake. Avoid any segregation of the mixture or

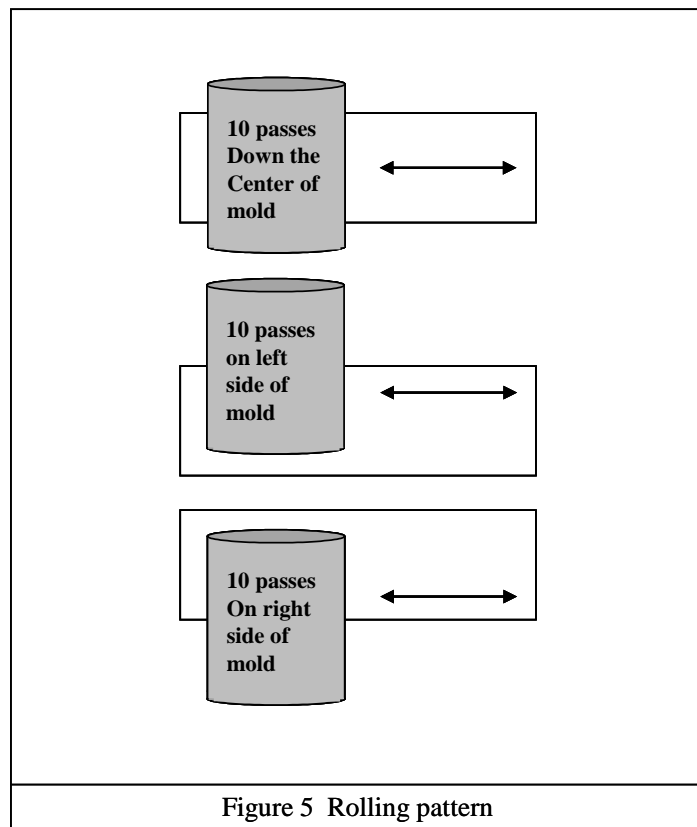
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tumbling of the coarse aggregate. Repeat this process until the material required to achieve the target air void content (all of the pre-weighted material) is in the mold. Tamp the mixture with a spade to achieve as level a surface as possible. The tamping pattern should entail 10 tamps along the length of the mold perpendicular to the rolling direction followed by 10 tamps parallel to the rolling direction on alternating sides along the entire length of the mold. A single layer is used in the compaction process.”

11.4.4 - Replace with:

“Apply 10 passes with the roller straddling the mold (Figure 5). One pass is the movement of the wheel in one direction over the entire ingot. When necessary, asphalt adhering to the wheel should be scrapped off and replaced in the mold and displaced material on the sides of the mold should be pushed back to the center of the mold with a spade. Apply a second series of 10 passes with the roller on the left half of the mold, a third series of 10 passes with the roller straddling the mold, a fourth series of 10 passes on the right half of the mold and a fifth series of 10 passes with the roller straddling the center of the mold. Compaction is complete when the roller rides on the steel of the mold frame for the entire length of the mold. If complete compaction has not been achieved after 50 passes the above pattern should be repeated. When compacting, each pass of the roller must extend from the ramp to the platform in a continuous motion, with no stops on the mixture.”



11.6 - Replace with:

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“After the slab is completely cooled, chalk arrows on the surface indicating the direction of the rolling wheel in order that specimens can be correctly oriented in later testing. Then remove the slab from the mold together with the removable base of the mold (constructed of particle board) before placing on a pallet jack.”

11.7 - Replace with:

“Core or saw the slab, using water as coolant, into the desired specimen shapes as soon as possible. Do not obtain the specimens from the outside edges (50 – 65 mm) of the slab. The edges are approximately 2 to 2.5 times the nominal size of the aggregate used. Store approximately 3 kg of the wasted mix for the determination of the theoretical maximum specific gravity if desired.”

11.8 - Add:

“For preparing Hamburg Wheel-Tracking Test specimen from ingot or slab, the specimen test height should be obtained by trimming bottom only, leaving top uncut.”

2. SHEAR TESTING

Shear testing shall be carried out according to AASHTO T320-03¹, “Standard Method of Test for Determining the Permanent Shear Strain and Stiffness of Asphalt Mixtures Using the Superpave Shear Tester”, with the following modifications:

Only Procedure C, “Repeated Shear Test at Constant Height,” is required.

Also:

2.1 - Replace T312 with PP3-94. “Standard Practice for Preparing Hot Mix Asphalt Specimens By Means of the Rolling Wheel Compactor.” Delete T166, “Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens.” Add T275, “Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens.” Substitute a thin adherent plastic wrap (Parafilm “M”) for the paraffin coating specified.

6.2.4 - Replace with:

“After the short-term conditioning is complete, the asphalt concrete mixture specimen should be compacted to the appropriate percentage of air voids using PP3-94. For the repeated shear test and associated analysis, the percentage air voids in the test specimen (which may be cut to the appropriate dimensions of 150 mm diameter and 50 mm height) should be 3.0 ± 0.3 percent. For the simple shear and shear frequency sweep tests, the percentage of air voids in the test specimen (which may be cut to the appropriate dimensions of 150 mm diameter and 50 mm height) should be 6.0 ± 0.3 percent. To achieve these target air voids, it may be necessary to compact the specimen (before cutting) to a slightly higher percentage of air voids.”

6.2.6 - Replace with:

¹ AASHTO T320-03, “Standard Method of Test for Determining the Permanent Shear Strain and Stiffness of Asphalt Mixtures Using the Superpave Shear Tester” is the most recent revision of AASHTO TP7-94, “Standard Test Method for Determining the Permanent Deformation and Fatigue Cracking Characteristics of Hot Mix Asphalt Using the Simple Shear Test (SST) Device” referenced in the project special provisions.

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- “Determine the percentage of air voids in the test specimens in accordance with T209, T269 and T275. Substitute a thin adherent plastic wrap (Parafilm “M”) for the paraffin coating specified. Determine the height of the test specimens in accordance with ASTM D3549.”
- 6.3.2 - Replace with:
“Determine the percentage of air voids in the test specimens in accordance with T209, T269 and T275. Substitute a thin adherent plastic wrap (Parafilm “M”) for the paraffin coating specified. Determine the height of the test specimens in accordance with ASTM D3549.”
- 6.4.2 - Replace with:
“Determine the percentage of air voids in the test specimens in accordance with T209, T269 and T275. Substitute a thin adherent plastic wrap (Parafilm “M”) for the paraffin coating specified. Determine the height of the test specimens in accordance with ASTM D3549.”
- 6.5.3 - Replace with:
“Apply a thin coating of the adhesive to the top of the test specimen and to the bottom platen. Orientate the specimen such that it is parallel to the direction of compaction and shear stresses and strains will be applied in the same direction as the compaction device (rolling wheel) or traffic. Center the test specimen on the bottom platen and lower the top platen onto the specimen. Rotate the specimen slightly back and forth to ensure good bonding, ensuring that the original orientation position is maintained.”
- 8.7.2 - Replace with:
“The data collection schedule should be set to collect at least 20 points evenly distributed between each logarithm cycle from 10 repetitions to 100,000 repetitions. Data should also be collected at 30,000 repetitions.
- 9.7.2 - Replace with:
“Continue the test sequence for 30,000 repetitions or until the shear LVDT exceeds its range (usually at 2.5 mm or 5 percent shear strain).”
- 9.8 - Replace Note 19 with:
“The repeated shear test at constant height takes approximately 6 hours to execute from the time the specimen is removed from the conditioning chamber until the test is completed and the specimen is removed from the shear tester.”
- 10.3 - Remove “(nominally 5000 cycles)” from the sentence.
- 10.4 - Add:
“For tests that do not reach 5 percent permanent shear strain with 30,000 repetitions, the repetition to 5 percent shear strain must be extrapolated. The extrapolation is done using the following method:
1. Plot $\ln(-\ln PSS)$ versus $\ln(n)$,
where PSS is the permanent shear strain at repetition n and \ln is the natural logarithm.
 2. Select the test points between $\ln(n_f)$ and $\ln(n_f) - 1.5$ (or the recognizable straight portion of the curve),
where n_f the final repetition, is the minimum interval to obtain the intercept (a) and slope (b) parameters of the following linear regression formulation:

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$$\ln \left(\ln PSS \right) = a + b \cdot \ln \left(n \right)$$

3. Determine the repetitions to 5 percent shear strain (*Cycle5PSS*) using the following equation,

$$Cycle5PSS = \exp \left(\frac{\ln \left(\ln 0.05 \right) - a}{b} \right)$$

An interpolation procedure is applied when the permanent shear strain reaches 5 percent in less than 30,000 repetitions. The following procedure should be used:

1. Prepare a table with load repetitions and *PSS* values, where *PSS* is the permanent shear strain at repetition *n*.
2. Determine the repetitions to 5 percent shear strain using a linear interpolation between two points that have *PSS* values immediately below and above the 0.05.”

11.4.1 - Replace with:

“For each specimen, report the number of repetitions required to obtain 5 percent permanent shear strain.”

3. FATIGUE AND STIFFNESS TESTING

Fatigue and stiffness testing shall be carried out according to AASHTO T321-03², “Standard Method of Test for Determining the Fatigue Life of Compacted Hot Mix Asphalt Subjected to Repeated Flexural Bending”, with the following modifications:

2.1 - Add T275 – “Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens”

6.2.4 - Add:

“Use Devcon 10240 5-minute epoxy.”

7.1 - Replace with:

“*Laboratory-mixed and Compacted Specimens* – Sample asphalt binder in accordance with T40 and sample aggregate in accordance with T2. Prepare three replicate hot-mix asphalt beam specimens sawn from slabs compacted in accordance with PP3.

Note 1 - The type of compaction device may influence the test results.

Note 2 - Normally test specimens are compacted using a standard compactive effort. However, the standard compactive effort may not reproduce the air voids of roadway specimens measured according to T269 and/or T275. If specimens are to be compacted to a target air void content, the compactive effort to be used should be determined experimentally.”

² AASHTO T321-03, “Standard Method of Test for Determining the Fatigue Life of Compacted Hot Mix Asphalt Subjected to Repeated Flexural Bending” is the most recent revision of AASHTO TP8-94, “Standard Test Method for Determining the Fatigue Life of Compacted Hot Mix Asphalt (HMA) Subjected to Repeated Flexural Bending” referenced in the project special provisions

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- 7.2 - Replace with:
“*Plant-mixed Laboratory Compacted Specimens* – Obtain HMA samples in accordance with T168. Prepare three replicate hot-mix asphalt beam specimens sawn from slabs compacted in accordance with PP3 (see Notes 1 and 2).”
- 7.4 - Replace with:
“Saw at 6 mm from both sides of each test specimen to provide smooth, parallel (saw cut) surfaces for mounting the measurement gages. The final required dimensions, after sawing, of the specimens are at 380 ± 6 mm in length, 50 ± 3 mm in height and 63 ± 3 mm in width.”
- 8.2 - Replace title with: “*Epoxying Nut to Neutral Position on Specimen* –”.
- 8.2 - Replace Figure 2 title with: “Nut Epoxied to Neutral Position on Specimen”.
- 8.8 - Replace with: “Set the deflection level (strain level) to the prescribed value.”
- 8.9 - Add:
“The data collection schedule should be set to collect at least 20 points evenly distributed between each logarithm cycle from 10 repetitions to 10,000,000 repetitions. Data should be also collected at 5,000,000 repetitions.”
- 9.1.1 - Replace with:
“*Maximum Tensile Stress (Pa)*:

$$\sigma_t = \frac{aP}{bh^2}$$

where:

a = space between inside and outside clamps

P = load applied by actuator in Newtons

b = average specimen width in meters

h = average specimen height in meters”

- 9.1.6 - Change units of y-axis in Figure 6 to MPa.
- 9.1.7 - Replace with:
“*Initial Stiffness (Pa)* – The initial stiffness is determined by plotting stiffness (S) against load cycles (n) and best-fitting the data to an appropriate exponential function, an example of which is shown in Equation 7. Figure 7 presents a typical plot of stiffness versus load cycles. The constant A represents the initial stiffness.

$$S = Ae^{bn}$$

where:

e = natural logarithm to the base e

A = constant

b = constant”

- 9.1.7 - Change units of y-axis in Figure 7 to MPa.
- 9.1.8 - Delete this paragraph (duplicate of 9.1.7).
- 9.1.9 - Change to
“*Cycles to failure* – Failure is defined as the point at which the specimen stiffness is reduced to 50 percent of the initial stiffness. The load cycle at which failure occurs should be interpolated or extrapolated from the test data. For tests

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in which the stiffness is not reduced by 50 percent after 5 million repetitions, the number of repetitions to 50 percent stiffness reduction is extrapolated using the following method:

1. Plot $\ln(-\ln SR)$ versus $\ln(n)$,
where SR is the stiffness ratio defined as the ratio of stiffness at repetition n over the initial stiffness (9.1.7 or 50th repetition) and \ln is the natural logarithm.
2. Select the test points between $\ln(n_f)$ and $\ln(n_f) - 2$ (or the recognizable straight portion of the curve),
where n_f the final repetition, is the minimum interval to obtain the intercept (a) and slope (b) parameters of the following linear regression formulation:

$$\ln(-\ln SR) = a + b \cdot \ln(n)$$

3. Determine the fatigue life (N_f) using the following equation,

$$N_f = \exp\left(\frac{\ln(-\ln 0.5) - a}{b}\right)$$

An interpolation procedure is applied when the specimen stiffness is reduced to 50 percent of the initial stiffness in less than 5,000,000 repetitions. The following procedure should be used:

1. Prepare a table with load repetitions and SR values, where SR is the stiffness ratio, defined as the ratio of stiffness at repetition n over the initial stiffness (9.1.7 or 50th repetition).
2. Determine the fatigue life (N_f) using a linear interpolation between two points that have SR values immediately below and above the 0.5.”

10.5 - Replace with: “Report the initial flexural stiffness in mega Pascals (MPa)”.

4. HAMBURG WHEEL-TRACK TESTING

Hamburg Wheel-Track testing shall be carried out according to AASHTO T324-04, “Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA), with the following modifications:

- 2.1 - Either AASHTO T312 or PP3-94 with changes noted in Rolling Wheel Compaction, may be used to prepare specimens.
- 5.1 - Replace with:
“*Hamburg Wheel-Tracking Machine* – An electrically powered machine capable of moving a 203.2-mm (8-in.) diameter, 47-mm (1.85-in.) wide steel wheel over a test specimen. The load on the wheel is 705 ± 4.5 N (158 lb \pm 1.0 lb). The wheel shall reciprocate over the specimen, with the position varying sinusoidally over time. The wheel shall make approximately 52 passes across the specimen per minute. The maximum speed of the wheel shall be

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approximately 0.305 m/s (1 ft/sec) and will be reached at the midpoint of the specimen.”

6.1 - Replace with:

“*Number of Test Specimens* – There shall be eight cylindrical specimens or four slab specimens prepared for four tests. Each test includes two cylindrical specimens or one slab specimen.”

6.2.6 - Replace with:

“*Laboratory Compaction of Specimens* – Specimens compacted in the laboratory shall be either compacted slab specimens using a Rolling Wheel compactor (RWC) or cylindrical specimens prepared by a Rolling Wheel Compactor or a Superpave Gyratory Compactor (SGC).”

6.2.6.1 - Replace with:

“*Compacting RWC Slab Specimens* – Material shall be compacted into slab using a Rolling Wheel Compactor (or equivalent). Compacted slab shall be cooled at normal room temperature on a clean, flat surface until the specimen is cool to the touch. The saw-cut slab specimen shall be 320 mm (12.60 in.) long and 260 mm (10.24 in) wide. A slab specimen thickness of 38 mm (1.50 in.) to 100 mm (3.94 in.) can be used. The slab specimen thickness shall be at least twice the nominal maximum aggregate size. The specimen test height should be obtained by trimming bottom only, leaving top uncut.”

6.2.6.2 - Replace with:

“*Compacting RWC Cylindrical Specimens* – Material shall be compacted into slab using a Rolling Wheel Compactor (or equivalent). Compacted slab shall be cooled at normal room temperature on a clean, flat surface until the specimen is cool to the touch. A cored cylindrical specimen from the slab should be 150 mm (5.91 in.) in diameter with a specimen thickness of 38 mm (1.50 in.) to 100 mm (3.94 in.). The specimen thickness shall be at least twice the nominal maximum aggregate size. The specimen test height should be obtained by trimming bottom only, leaving top uncut.

Compacting SGC Cylindrical Specimens – Material shall be compacted into specimens using an SGC according to T 312. A specimen thickness of 38 mm (1.50 in.) to 100 mm (3.94 in.) can be used. The specimen thickness shall be at least twice the nominal maximum aggregate size. Two 150-mm (5.91 in.) diameter specimens are needed. Compacted specimens shall be cooled at normal room temperature on a clean, flat surface until the specimen is cool to the touch.”

6.3.2 - Replace with:

“*Laboratory Compaction of Specimens* – Specimens compacted in the laboratory shall be either compacted slab specimens using a Rolling Wheel compactor (RWC) or cylindrical specimens prepared by a Rolling Wheel Compactor or a Superpave Gyratory Compactor (SGC).”

6.3.2.1 - Replace with:

“*Compacting RWC Slab Specimens* – Material shall be compacted into slab using a Rolling Wheel Compactor (or equivalent). Compacted slab shall be cooled at normal room temperature on a clean, flat surface until the specimen is cool to the touch. The saw-cut slab specimen shall be 320 mm (12.60 in.) long and 260 mm (10.24 in) wide. A slab specimen thickness of 38 mm (1.50 in.) to

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100 mm (3.94 in.) can be used. The slab specimen thickness shall be at least twice the nominal maximum aggregate size. The specimen test height should be obtained by trimming bottom only, leaving top uncut.”

6.3.2.2 - Replace with:

“*Compacting RWC Cylindrical Specimens* – Material shall be compacted into slab using a Rolling Wheel Compactor (or equivalent). Compacted slab shall be cooled at normal room temperature on a clean, flat surface until the specimen is cool to the touch. A cored cylindrical specimen from the slab should be 150 mm (5.91 in.) in diameter with a specimen thickness of 38 mm (1.50 in.) to 100 mm (3.94 in.). The specimen thickness shall be at least twice the nominal maximum aggregate size. The specimen test height should be obtained by trimming bottom only, leaving top uncut.

Compacting SGC Cylindrical Specimens – Material shall be compacted into specimens using an SGC according to T 312. A specimen thickness of 38 mm (1.50 in.) to 100 mm (3.94 in.) can be used. The specimen thickness shall be at least twice the nominal maximum aggregate size. Two 150-mm (5.91 in.) diameter specimens are needed. Compacted specimens shall be cooled at normal room temperature on a clean, flat surface until the specimen is cool to the touch.”

6.4.1 - Add:

“The specimen test height should be obtained by trimming bottom only, leaving top uncut.”

7.3 - Replace with:

“Determine the air void content of the specimens in accordance with T 269. It is recommended, for laboratory-compacted specimens, that the target air void content be 7.0 ± 1.0 percent. Field specimens may be tested at the air void content at which they are obtained.”

8.1 - Replace with:

“*Slab Specimen Mounting* – Use Plaster-of-Paris to rigidly mount the specimen in the mounting trays. The plaster shall be mixed at approximately a 1:1 ratio of plaster to water. Pour the plaster to a height equal to that of the specimen so that the air space between the specimen and the tray is filled. The plaster layer underneath the specimen shall not exceed 2 mm (0.08 in.). Allow the plaster at least one hour to set. If other mounting material is used, it should be able to withstand 890 N (200 lb) of load without cracking.

Cylindrical Specimen Mounting – Use plastic molds (specimen holders) and shims (spacer discs) to rigidly mount the specimens in the specimen trays as illustrated in Figures 1 and 2. The two cylindrical specimens should be cut to fit the specimen holders such that the directions of rolling wheel for both specimens are consistent with the direction of motion of Hamburg Wheel-Tracking Device.”

8.2 - Replace with:

“*Selecting the Test Temperature* – The test temperature shall be selected based upon the applicable specifications. Test at 50 °C (122 °F) temperature .

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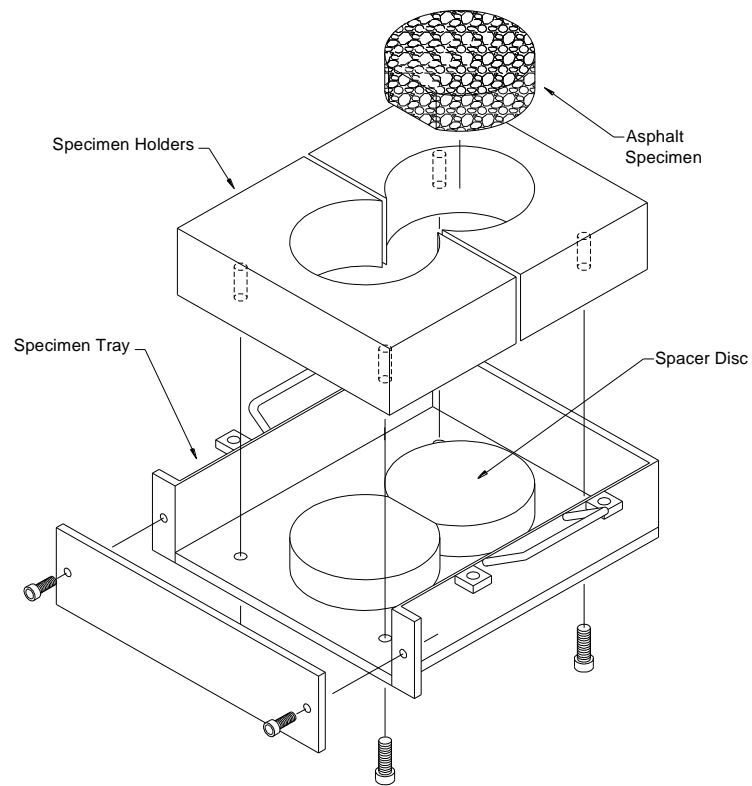


Figure 1 – Illustration of cylindrical specimen mounting configuration.

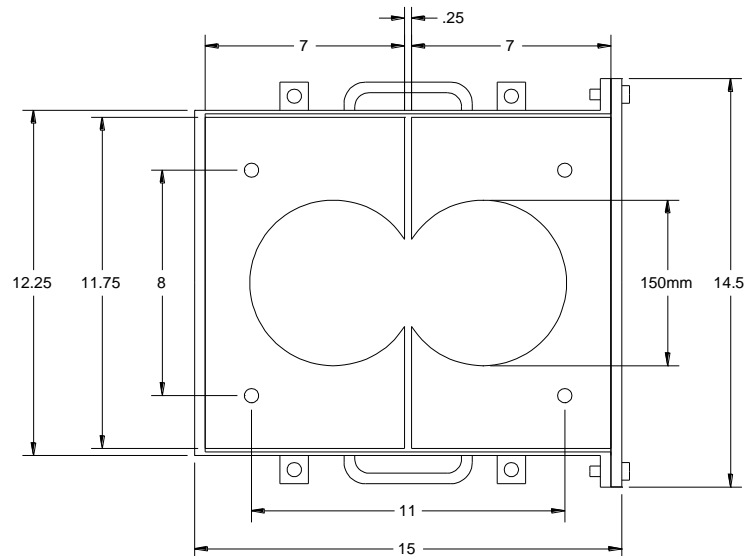


Figure 2 – Dimensions of the cylindrical specimen mounting configuration (Unit of length is in inches unless specified).

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- 9.1 - Replace with:

“Plot the average rut depth versus number of passes for each test. The average rut depth is defined as the average of ruts occurred at middle three profile positions. A typical plot of the output produced by the Hamburg Wheel-Tracking Device is shown in Figure 3. From this plot, obtain the following values:
Slope and intercept of the first steady-state portion of the curve.
Slope and intercept of the second steady-state portion of the curve.
- 9.2 - Add:

“For tests that do not present the Stripping Inflection Point with 20,000 passes, instead of reporting the failure rut depth and number of passes to failure, report the maximum impression at 20,000 passes.”
- 10.12 - Add:

“Average number of passes to failure of four tests; and”
- 10.13 - Add:

“Average maximum impression at 20,000 passes of four tests (For tests that do not present the Stripping Inflection Point).”